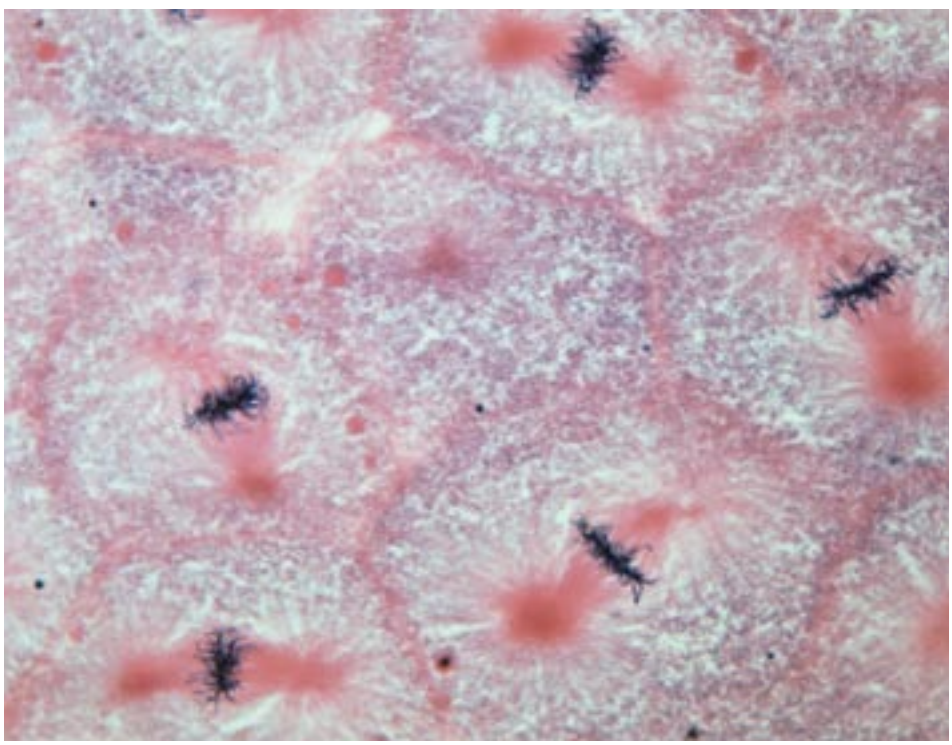
63 Show Me the Genes!

READING

Even before he began his experiments on pea plants in the 1860s, Mendel knew that the genes had to be in the male and female sex cells—the sperm (or pollen) and the egg. However, no one knew *where in the cell* the genes were located until fifty years later. An individual gene is too small to be seen with a light microscope. So how did the microscope enable scientists to figure out where in the cell the genes are located? Scientists studying dividing cells, like the one shown in the photo below, provided evidence to support Mendel's ideas.



CHALLENGE

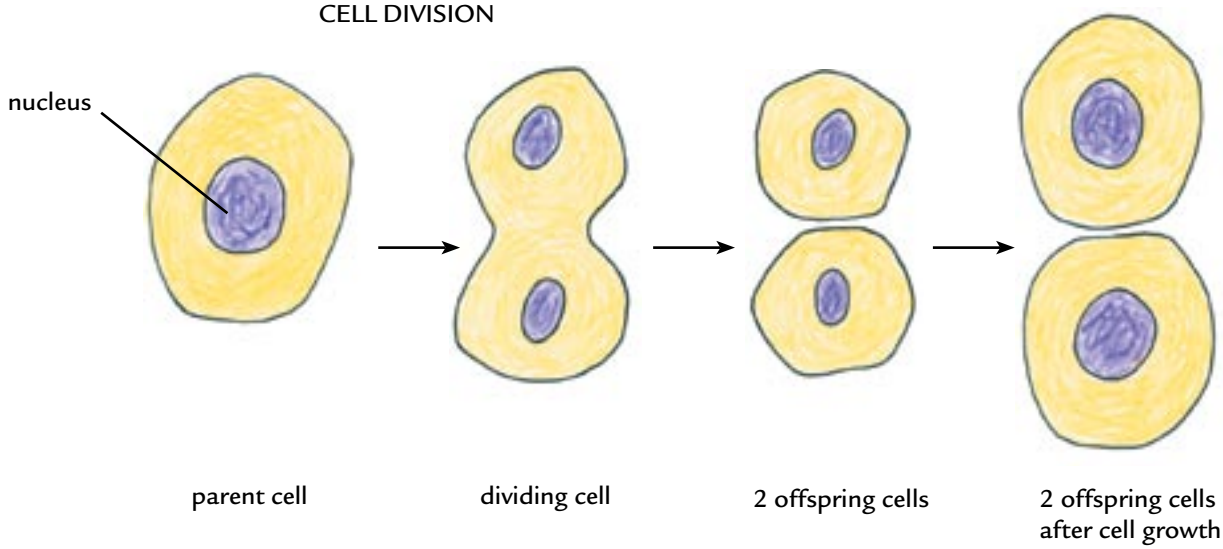
What role do chromosomes play in the inheritance of genes?

READING

Part A: Chromosomes and Cell Division

Every organism must make new cells. Single-celled organisms, such as bacteria, yeast, paramecia, and amoebas, use cell division to reproduce asexually. In multicellular organisms, cell division (shown below) is necessary for the organism to grow to adulthood and to replace injured and worn out cells. When you get a cut and lose some blood, additional new blood cells and new skin cells are produced from the division of cells in your body.

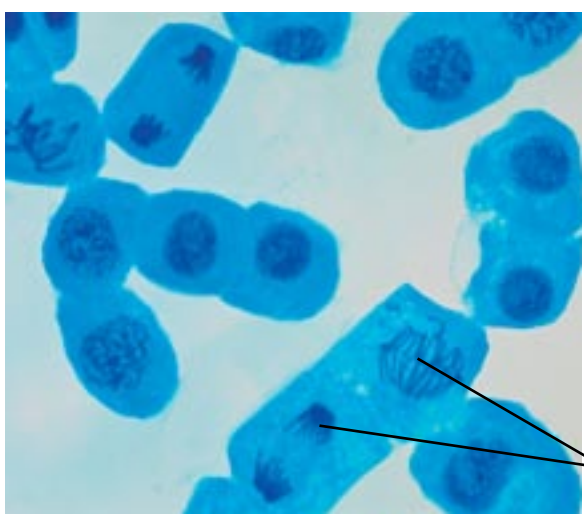
CELL DIVISION



STOPPING TO THINK 1

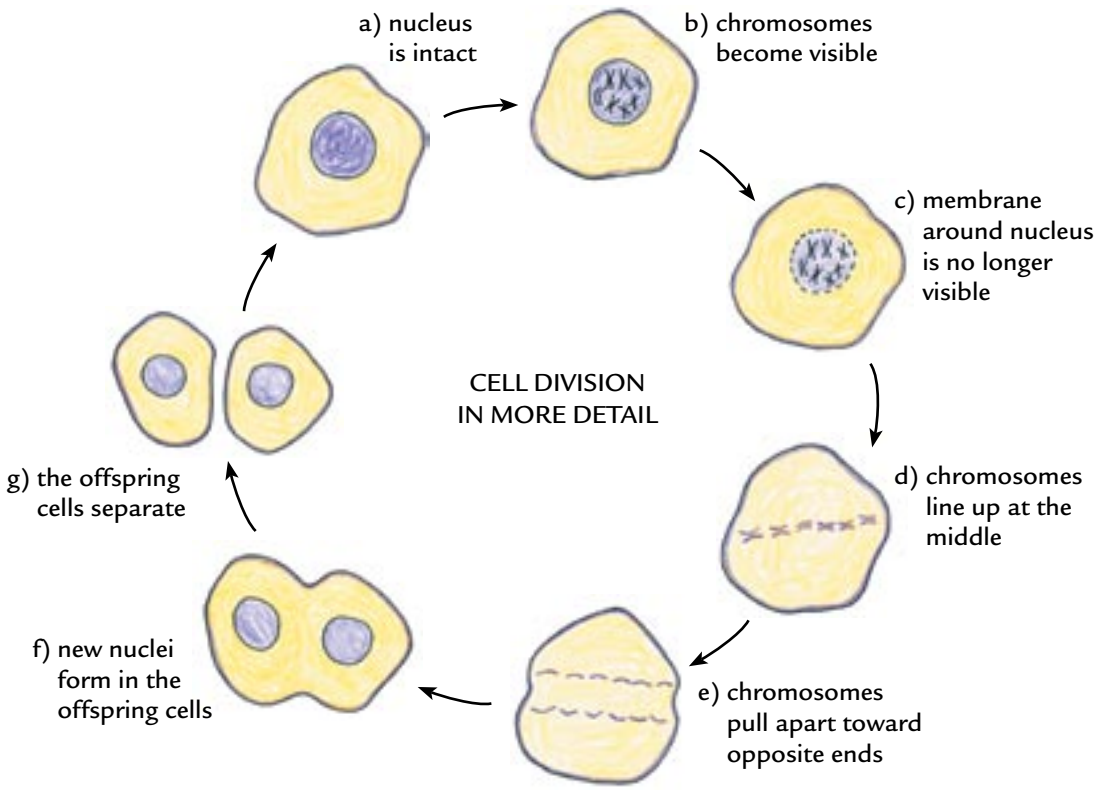
How is the function of cell division in single-celled organisms different from cell division in multicellular organisms?

CHROMOSOMES IN DIVIDING PLANT CELLS



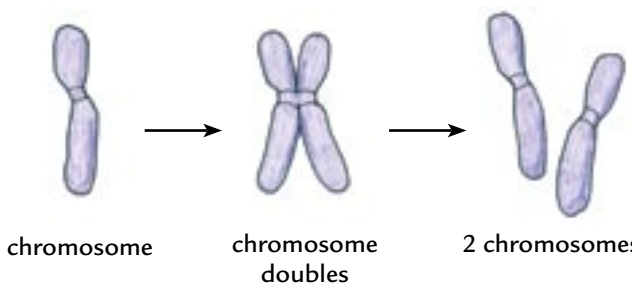
In the early 1900s, scientists studying cells in rapidly growing parts of plants made an interesting observation. They saw that just before cell division, the membrane around the nucleus was no longer visible and little dark structures, which they called **chromosomes**, appeared. When the cells split apart, the chromosomes were divided evenly between the two new cells.

When a cell is not dividing, the chromosomes are long, fine strands, like very thin spaghetti, packed into the nucleus of the cell. Before the cell divides, it makes copies of all its chromosomes so that its two offspring cells can each get a complete set. Then the chromosomes become coiled, which makes them visible when observed under a microscope. Finally, the cell divides, as shown below.



Each cell in a human body contains 46 chromosomes. When a human cell divides, the two cells that result each contain 46 chromosomes. How can 46 chromosomes become two sets of 46? It's not magic: each crisscrossed chromosome is two identical copies that are attached to each other. As you can see below, each doubled chromosome then splits during division to become two identical, but now separate, chromosomes.

A CHROMOSOME DURING CELL DIVISION

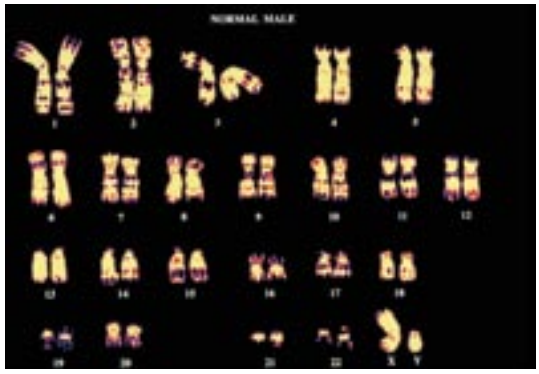


STOPPING TO THINK 2

What would happen to the number of chromosomes in each cell if copies of them were not made before cell division?

Part B: Chromosomes and Sexual Reproduction

The 46 chromosomes in a human cell can be sorted into 23 matching pairs, as shown below. Each chromosome looks identical to its partner, with one exception: pair number 23, which are also called the sex chromosomes. Female humans have two X-chromosomes, while males have one X-chromosome and one Y-chromosome.

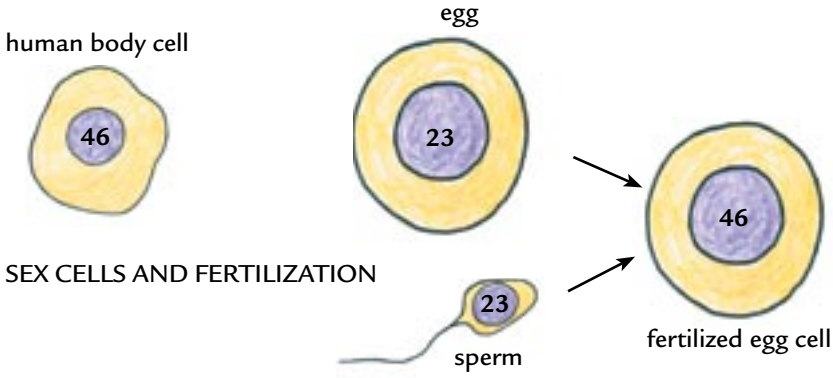


THE 46 CHROMOSOMES IN EVERY CELL OF A MALE HUMAN

These chromosomes were photographed in a flattened cell; the images of each chromosome were cut out and sorted by size.

Soon after the 23 pairs of chromosomes were observed, scientists declared that the 23 pairs of chromosomes behaved just like the genes in Mendel's model. What did they mean by that?

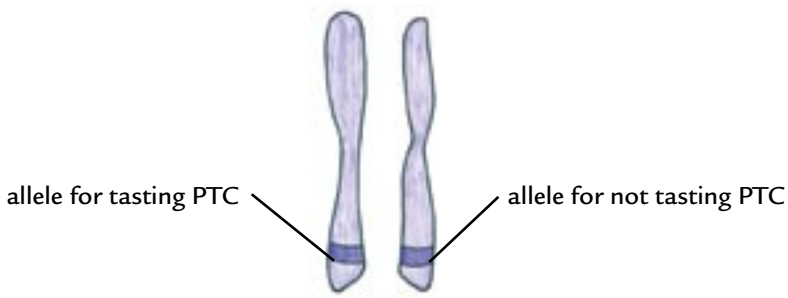
Sex cells (sperm and egg) are formed by a special kind of cell division, in which each cell receives copies of exactly half of the chromosomes. In humans, the body's cells contain 46 chromosomes, but the egg and sperm contain only 23 chromosomes. When a sperm fertilizes an egg cell to form the first cell of a new organism, the new cell has 46 chromosomes, as illustrated below. Half come from the mother and half come from the father.



STOPPING TO THINK 3

Why must the number of chromosomes in the sperm and egg be half the number of chromosomes in the other cells of an organism?

When sex cells are produced, exactly one member of each chromosome pair moves into each offspring cell. Thus, when an egg and a sperm cell come together in fertilization, the new cell has 23 complete pairs of chromosomes, or 46 total chromosomes. Think of the 23 pairs of chromosomes as 23 pairs of socks. An egg cell has one of each kind of sock, and a sperm cell has the matching sock for each of the egg's socks. Only when they come together, when the sperm fertilizes the egg, does the resulting cell contain 23 complete pairs of socks. One member of each pair has come from the female parent, and the other from the male parent. The chromosomes of each pair carry genes for the same characteristics (see below), but the two alleles of any one gene can be different, as you've learned before.



ALLELES IN HUMANS FOR THE ABILITY TO TASTE PTC

A matching pair of chromosomes contains two different alleles for PTC tasting, since this PTC-tasting person is heterozygous. The two alleles of the gene might differ in a single bit of genetic information.

By comparing the microscope evidence to the work of Gregor Mendel, scientists realized that the chromosomes must carry the genes. Once scientists understood the location of the genes and the way they were passed to offspring, they realized the importance of Mendel's work.

STOPPING TO THINK 4

Consider two children with the same two parents. Would you expect them to have the same sets of chromosomes? Explain why or why not.

Part C: So Many Genes . . .

Human cells contain approximately 30,000 pairs of different genes. However, the human nucleus contains only 23 pairs of chromosomes. Each gene is a small portion of a chromosome. Only by careful study can scientists determine which gene (or group of genes) is responsible for a specific trait, such as eye color or blood type in humans or seed color in pea plants.

Furthermore, the more complex the trait being studied, the greater the number of different genes which contribute to it. Even diseases such as cancer are proving to result from the combined effects of many genes.

The genes are part of a long molecule called DNA, which stands for deoxyribonucleic acid. Each chromosome contains a long DNA molecule. Sometimes, before a cell divides, a mistake is made in a gene when the DNA is copied to make a new set of chromosomes. These mistakes are called **mutations**. If the mutation occurs during the formation of a sex cell, an offspring that results from that sex cell will be affected by the mutation. Genes give instructions to the body. Even though some mutations don't make much difference and some are even helpful, most mutations are harmful.

A mutation in a gene is like a change in a word in a sentence. For example, consider the sentence, "I hear that noise." The four letters in the word "hear" communicate a meaning. What if we change one of the letters? The results might include

I h**e**er that noise.

I **f**ear that noise.

The first change makes the word look a little funny, but it still sounds the same, and the meaning of the sentence would be unchanged if you heard it spoken aloud. But the second change completely changes the meaning of the sentence. Like this change in the sentence, some mutations change the information provided by the genes in which they occur.

STOPPING TO THINK 5

How exactly does a mutation change the form of an organism? When do such mutations occur?

ANALYSIS

1. Draw a flow diagram (a series of pictures) such as the one below that shows the locations and relative sizes of DNA, genes, chromosomes, and cells in a human body. Write a paragraph to explain your diagram.